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Research Article

Indicators for mapping and assessment of ecosystem condition and of the ecosystem service habitat maintenance in support of the EU Biodiversity Strategy to 2020

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Abstract

A systematic approach to map and assess the “maintenance of nursery populations and habitats” ecosystem service (ES) (hereinafter called “habitat maintenance”) has not yet emerged. In this article, we present an ecosystem service framework implementation at landscape level, by proposing an approach for calculating and combining a series of indicators with spatial modelling techniques. Necessary conceptual elements for this approach are: a) ecosystem condition, b) supply and demand of the targeted ecosystem service and c) spatial relationships between the Service Providing Units (SPU) and the Service Connecting Units (SCU). Ecosystem condition is quantified and mapped based on two indicators, the Biodiversity State and the Anthropogenic Impact. Quantification and mapping of supply and demand are based on the hypothesis that high supply can be activated in strictly protected areas and that a demand is localised in the Natura 2000 sites (N2K), considering them as the Service Benefit Areas (SBA). Wetlands are assessed as SCU between the SBA and the landscape areas where the habitat maintenance ES is

supplied. By assessing wetlands as SCU, we intent to highlight their role as biodiversity stepping stones and as green infrastructures. Overall, we conclude that the EU biodiversity policy demand for no net loss and for a coherent N2K network can be met by enhancing the delivery of the habitat maintenance ES. This approach can assist policy-makers in prioritisation of conservation and restoration targets, in line with the EU biodiversity strategy to 2020 and the preparation of the post-2020 Strategy.

Keywords

Ecosystem services, ecosystem condition, habitat maintenance, service providing units, wetlands, Natura 2000

Introduction

Over the last few years, the need to incorporate Ecosystem Service (ES) assessment into the EU biodiversity strategy to 2020 (Target 2) has been continuously expressed in science reports and in the context of the EU policy initiatives to halt the loss of biodiversity and to ensure that the natural capital is sustainably managed. It has been stated that the direct and indirect causal links between biodiversity and ecosystem services should be identified to ensure their co-maintenance (Balvanera et al. 2013). Such an approach implies for a holistic and integrated comprehension of the underlying processes and links between ecosystem condition and the supply and demand of ESs (Maes et al. 2012; Vimal et al. 2012).

The EU policy response to biodiversity loss faces the challenge to maintain areas of high biodiversity value both within and outside the Natura 2000 (N2K) sites, through the implementation of the EU Habitats and Birds Directives, as underlined under Target 1 of the Biodiversity Strategy. Both Directives underscore the importance of wetland ecosystems as stepping stones or connecting ecosystems that, if adequately conserved / managed, can improve the coherence, connectivity and resilience of the N2K network. The ecological integrity of the surrounding landscape of the N2K network is also addressed by the EU Green Infrastructure (GI) Strategy, which is essential for meeting Target 2 of the Biodiversity Strategy for the maintenance and enhancement of ecosystems and their services. Reconnecting fragmented landscapes and nature reserves through green infrastructure elements (i.e. buffer zones around natural reserves), is determined as one strand of land development in the EU (Maes et al. 2015). The need to acknowledge nature as an integrated system at landscape level, rather than as individual parts, has been widely recognised (Rüdisser et al. 2012). Vimal et al. (2012) showed that effective biodiversity conservation measures must go beyond boundaries of protected areas and incorporate the spatial scale of ecological processes and the impact of human activities, inside and around protected areas. In particular, wetland conservation measures need to be implemented at landscape scale, to ensure the maintenance of species in broad geographic areas (i.e. Naugle et al. 2001).

The habitat maintenance ES

Under the Common International Classification of Ecosystem Services (CICES V5.1), biodiversity itself is considered as an ES, classified as “maintaining of nursery populations and habitats” (Haines-Young and Potschin 2018). Similarly, in the context of the Economics of Ecosystems and Biodiversity (TEEB 2010), the “habitats maintenance for species” ES is classified in the “habitat or supporting services” group.

Maintenance services are recognised as the difficult ESs to be mapped and assessed, both for the partial understanding of some biophysical processes and for the nature of these services, which underpin all the others (Maes et al. 2014). Furthermore, there are on-going discussions, whether biodiversity should be classified and to what extent, as an ES itself (e.g. Mace et al. 2012, Maes et al. 2014) or should be included in an ES context as an independent value, i.e. beyond being useful to humans (e.g. Schröter et al. 2014). As Liquete et al. (2016) stated, there is no consensus on the consideration of the nursery / habitat maintenance as a function and concluded that it can be considered as an ES on its own when it is linked to a concrete human benefit. The demand for maintaining habitats for species is also considered as a human benefit, since it preserves natural heritage and safeguards intrinsic human values (like well-being and recreation) at the same time (Burkhard et al. 2010; Burkhard et al. 2012a; Knight 1997). Other studies show that the structural diversity of a landscape (i.e. how fragmented it is) is crucial for the migration capacity of species and their adaptive capacity to climate change (Schneiders and Müller 2017) and that corridors are essential for protecting the processes and linkages required to support threatened species, particularly in terms of long-term adaptation to climate change (Derneği 2010).

Focusing on wetlands, Merken et al. (2015) demonstrate that the maintenance of habitat availability contributes to the improvement of functional connectivity. Green and Elmberg (2013) show that wetland habitats for migratory birds are critical as they contribute to other supporting and regulating ecosystem services including nutrient cycling, control and disease surveillance. Moreover, Wahlroos et al. (2015) stated that even artificial wetlands in urban landscapes provide critical habitat (successful breeding of amphibians and water birds occurred right after their construction) and beneficial functions. At the same time, the maintenance of habitats is evaluated by Okruszko et al. (2011) as the most fragile ecosystem service, amongst other services provided by a sample of 104 wetlands across Europe (i.e. supporting biomass service, carbon sequestration, nutrient removal, reed production). Abdul Malak et al. (2019) stressed, as a key policy message, that despite covering about 6% of the land surface and being geographically scattered, wetland ecosystems provide important connectivity between the air, land and water-related habitats and, therefore, mitigate anthropogenic pressures and deterioration.

Links between pressures, biodiversity, ecosystem condition and ES supply

EU environmental policies (Habitats Directive, Birds Directive, Water Framework Directive, Marine Strategy Framework Directive) recognise amongst others, the need to assess

ecosystem condition, in order to safeguard nature conservation. Mapping of condition is also necessary for identifying where mitigation actions are required (Burkhard et al. 2018).

Assessment of ecosystem condition refers to the analysis of the physical, chemical and biological condition or quality of ecosystems at a particular point in time and the impacts of major pressures to which they are exposed (EEA 2015a). If impacts or condition cannot be quantified, pressures are also used as indicators of ecosystem condition (Erhard et al. 2016; Burkhard et al. 2018). Indicators reflecting habitat quality, attempt to interpret the ecological value and anthropogenic pressures of the examined sites (Drakou et al. 2011; Notte et al. 2012; Hossain et al. 2017). The most recent analytical framework for mapping and assessment of ecosystem condition (Maes et al. 2018) proposes pressures indicators and condition indicators (environmental quality - physical and chemical quality and ecosystem attributes-biological quality), based on compilation of individual metrics. Moreover, it recognises the need for composite indicators on ecosystem condition that can reflect the overall quality of an ecosystem asset in terms of its characteristics. In our study, we examined pressure indicators and indicators based on biological quality.

Pressures affecting ecosystem condition include habitat change, pollution and nutrient enrichment, overexploitation, invasive alien species and climate change (Derneği 2010; EEA 2015a). Particularly, the habitat change, including loss, degradation and fragmentation, is considered as a major pressure in all types of ecosystems (Maes et al. 2018). It is driven mainly by intensive agriculture and urbanisation (EEA 2015b), while increasing impervious surface coverage affects ecosystem integrity, reduces biological diversity, increases isolation and spreads disturbance, such as the spread of invasive species (Jaeger et al. 2011).

The assessment of biological quality includes biodiversity features, from genes, individuals and populations to species, habitats and ecosystems (Gaston et al. 2008). So far, many initiatives focus on biodiversity indicators (status of protected species, assessment of extinction risk of threatened species, habitat distribution and trends in the abundance and distribution of populations of selected common species) (McGarigal and McComb 1995; Riitters et al. 1997; Rüdisser et al. 2012; Maes et al. 2014). Common bird species are also proposed as good proxies for the diversity and integrity of ecosystems, since they are key elements of the biomass, structure and functioning of ecosystems and can be used as indicators of habitat quality (Vallecillo et al. 2016). Moreover, data on species diversity and abundance, monitored under EU Nature Directives, are proposed by the MAES 5th Technical Report (Maes et al. 2018) as metrics to assess biological quality.

Links exist between pressures, biodiversity, ecosystem condition and ES supply (EEA 2015a). Theoretically, an ecosystem is likely to be in a good condition if pressures are absent. Many studies have examined the relationship between Biodiversity State and ES supply (Quijas et al. 2010; Duru et al. 2015; Soliveres et al. 2016, Pastur et al. 2016). Additionally, based on findings of Manolaki and Vogiatzakis (2017), the highest capacity of ES provision is detected in semi-natural habitat types, rich in biodiversity. However, up to now, there is a lack of quantitative data linking ecosystem condition to the ecosystem potential capacity to deliver services (Erhard et al. 2016; Maes et al. 2016). Maes et al.

(2016) support that existing datasets of biodiversity and anthropogenic pressures should be used in a fruitful and innovative way to assess the ecosystem condition.

Conceptual framework

Based on the Millennium Ecosystem Assessment (MEA) definition, ecosystem condition is the capacity of an ecosystem to deliver ES, relative to its potential capacity (MEA 2005) and can form an indicator of the ecosystem's natural potential (Maes et al. 2013; Liquete et al. 2016).

According to Burkhard et al. (2014) framework, ES flow is based on the ecosystem condition (natural potential to deliver ES), ES supply and demand. Overall, ESs are the contributions of ecosystem function to human well-being and their supply is activated by additional inputs (Burkhard et al. 2012b) that may represent anthropogenic contributions to ecosystem services (i.e. existence of protected areas, restoration of degraded natural areas, construction of artificial wetlands etc.). These inputs can act together with the natural potential and enable the identification of the spatial units within which the ecosystem service is provided (Service Providing Units - SPUs) (Potschin-Young et al. 2018). Service Benefit Areas (SBAs) are the spatial units that benefit from the ecosystem service and to which the ecosystem service flow is delivered (Potschin-Young et al. 2018). SPUs and SBAs may partially overlap or, if not adjacent, may be connected by spatial units, called Service Connecting Units (SCUs), resulting in different types of spatial relationships (Luck et al. 2003; Fisher et al. 2009; Kontogianni et al. 2010; Syrbe and Walz 2012; Burkhard et al. 2014). SCUs influence the transfer of the benefit from SPUs to SBAs and can be either natural (i.e. wetlands) or anthropogenic (i.e. road network).

This study proposes an adaptation of Burkhard et al. (2014) cascade framework as a methodological approach in the case of the “maintenance of nursery populations and habitats” ecosystem service (CICES V5.1), hereinafter called "habitat maintenance" ES (Fig. 1). It covers the mapping and assessment at landscape level of: (i) the ecosystem condition, (ii) the supply of the habitat maintenance ecosystem service (using the existence of protection as additional input) and (iii) the ES flow from SPUs to SBAs (considering the N2K sites as the SBAs). Wetlands, if are not located within SPUs and SBAs, are scattered at the wider landscape and are considered as SCUs.

In addition, it aims to demonstrate that the EU biodiversity policy demand for no net loss and for a connected N2K network can be met by enhancing the delivery of the habitat maintenance ES, considering also that wetland ecosystems improve the habitat maintenance ES flow, by representing biodiversity stepping stones and green infrastructures.

The following research questions were used to guide the study:

- How can we map and assess ecosystem condition, based on indicators that combine pressures and biodiversity state?

- How can we link the delivery of the habitat maintenance ES with the ecosystem condition, within the context of the EU biodiversity strategy demands?
- How can we assess the spatial relationships between the SPUs, the N2K sites (areas as SBAs) and SCUs (i.e. wetlands), in order to assist policy-makers in the identification and prioritisation of conservation and restoration areas?

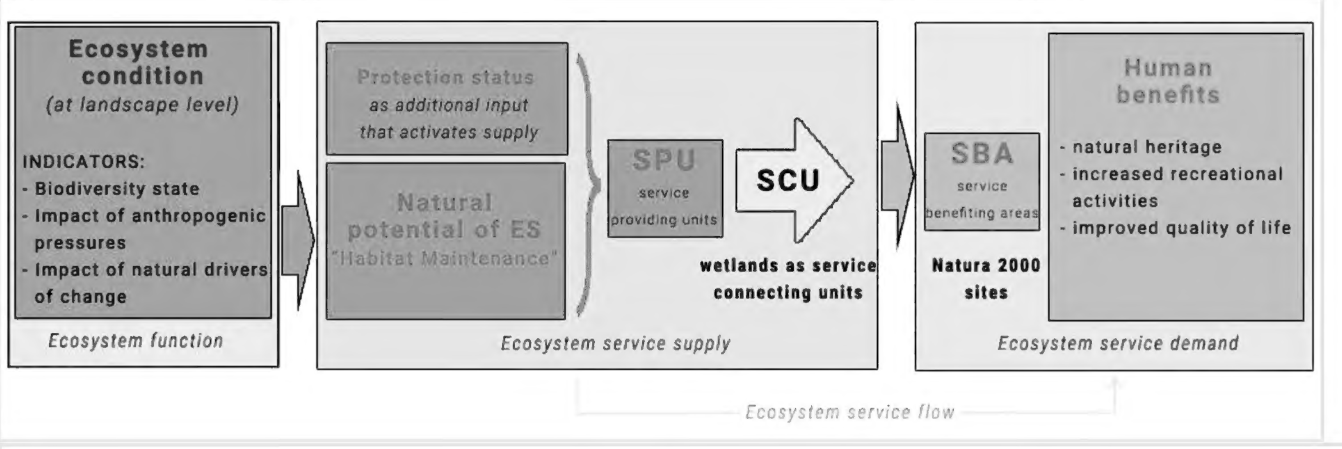

Figure 1.

Conceptual framework of the assessment of the habitat maintenance ES (Adapted from Burkhard et al. 2014).

Methods and data

The mapping and assessment of ecosystem condition and of the habitat maintenance ES supply are carried out at landscape level and include a series of indicators and spatial modelling techniques (Fig. 2). They are based on high resolution Earth Observation (EO) mapping products and the most up-to-date and publicly available European and national (submitted under EU reporting obligations) datasets:

- Copernicus Land Local Component “Urban Atlas”. Source: Copernicus Land Monitoring service (https://land.copernicus.eu/) of the European Environment Agency (EEA). Reference year: 2012.
- Copernicus pan-European component CORINE Land Cover (CLC). Source: Copernicus Land Monitoring service (https://land.copernicus.eu/) of EEA. Reference year: 2012.
- Wetlands layer. Source: Greek Biotope Wetland Centre (EKBY). Reference year: 2017. Scale: 1:5000.
- Natura 2000 database. Source: Central Data Repository (CDR) of European Environment Information and Observation Network (EIONET) (https://cdr.eionet.europa.eu/gr/eu/n2000/). Reference year: 2012.
- National designated areas. Source: Common Database on Designated Areas (CDDA) available at CDR of EIONET (https://cdr.eionet.europa.eu/gr/eea/cdda1/). Reference year: 2017.
- Habitats/Species Conservation Status and geographical distribution. Source: Report on Implementation Measures of Article 17 of Habitats Directive, available at

CDR of EIONET (https://cdr.eionet.europa.eu/gr/eu/art17/). Reference period: 2007 to 2014.

- Birds Population Trends and geographical distribution. Source: Report on Implementation Measures of Article 12 of Birds Directive, available at CDR of EIONET (https://cdr.eionet.europa.eu/gr/eu/art12/). Reference period: 2008 to 2014.
- EU List of Common birds. Source: Pan-European Common Bird Monitoring Scheme - PECBMS (http://ebcc.birdlife.cz/european-wild-bird-indicators-2017-update/) Reference year: 2017.
- Census data. Source: Hellenic Statistical Authority (http://www.statistics.gr/el/2011-census-pop-hous). Reference year: 2011.
- Administrative spatial units for Greek municipalities based on Greek law 3852/2010. Source: Hellenic Republic, Ministry of Administrative Reconstruction. Central catalogue of public data (http://www.data.gov.gr). Reference year: 2010.

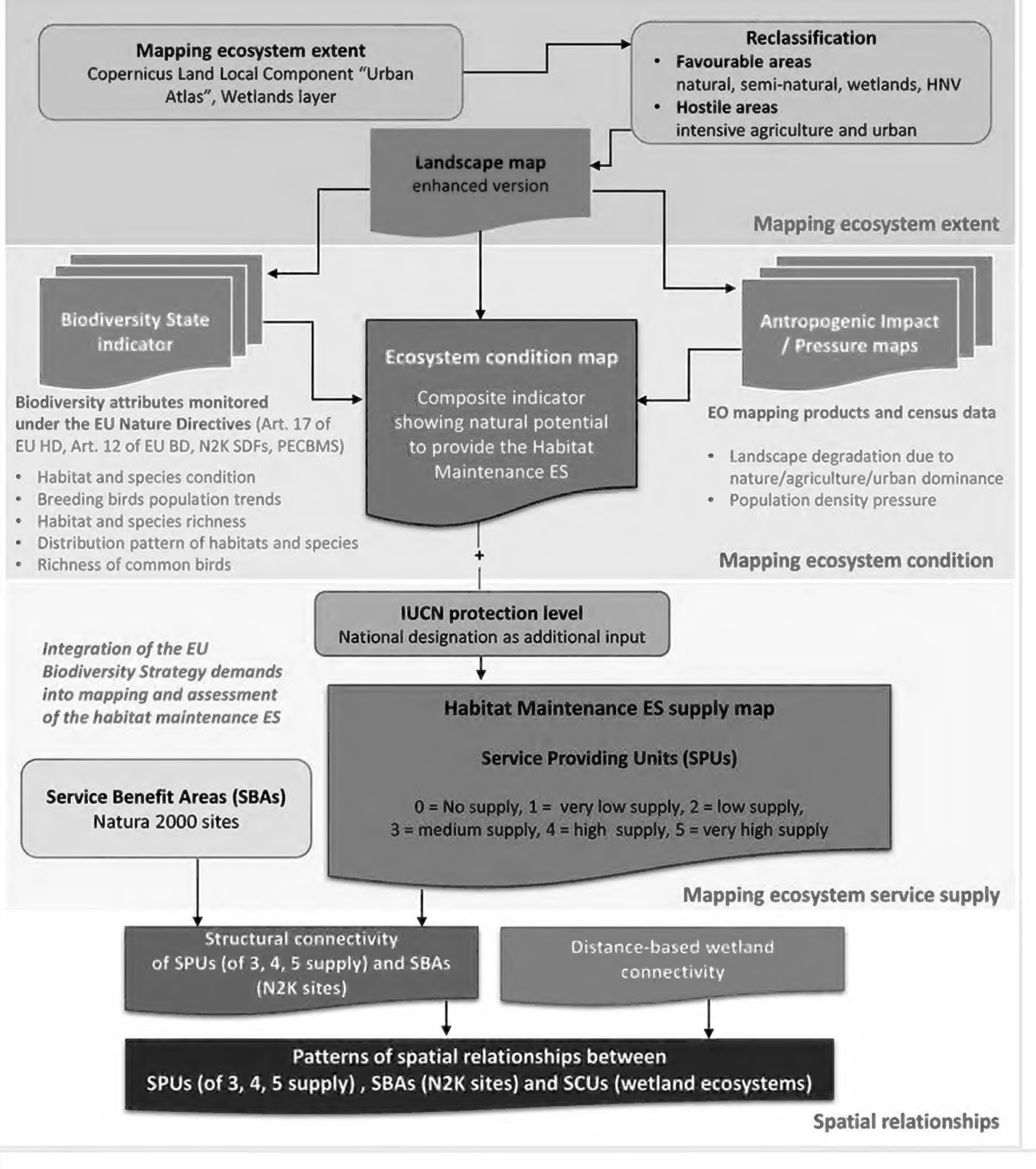

Figure 2.

Methodological flow for the assessment of the habitat maintenance ecosystem service.

Ecosystem condition, which reflects the natural potential, is quantified and mapped, based on two indicators: the Biodiversity State and the Anthropogenic Impact. By focusing on the habitat maintenance ES, we investigate whether the natural potential could be either reduced or activated by the absence or presence of conservation measures. Thus, to finally assess the ES Supply, we examine the level of protection that is applied at nationally designated areas. The demand for the habitat maintenance ES is localised in N2K sites, which are hosting important natural habitats, wild fauna and flora. These could benefit by the surrounding landscape mosaic, when the habitat maintenance ES is supplied. Wetland ecosystems are assessed as SCU between the SBA and the landscape areas, in accordance with the degree of the habitat maintenance ES supply.

Study area

The methodological framework has been applied in an area of 303572.96 ha in the Attica region, which is the metropolitan region of Athens, Greece. It is an area of high population density, where various human activities are often competing with nature conservation efforts. Nine (9) N2K sites are included, covering 12% of the total study area. Nationally designated areas include areas of strict protection (Parnitha and Sounio National Parks and Lake Vouliagmeni Natural Monument) and areas of moderate protection (Shinias-Marathonas National Park, an aesthetic forest, a game breeding station and several nature reserve zones and wildlife refuges). They also include areas for which restrictions of various protection level apply partially to certain zones. There is weak or no protection for 81% of the study area. Most of Attica Region’s wetlands are small (below 8 ha), outside protected areas, scattered in heavily degraded semi-natural areas and are continuously threatened by human activities. However, at the same time, they create a network in urban and rural settings, which hosts important habitats and safe breeding grounds for species, such as migratory birds. As such they can be considered as green infrastructures (European Commission 2013) that could be managed and conserved to deliver a wide range of ecosystem services, including biodiversity improvement and opportunities for recreation and contact with nature, water storage and retention, flood mitigation, water quality improvement, adaptation to climate change etc.

Mapping of favourable and hostile units

Our conservation objective is natural and semi-natural areas that are considered favourable landscape units for nursery populations, for species reproduction, movement and dispersal as breeding, rearing, moulting, wintering or staging areas at the landscape level (Estreguil et al. 2013). Artificial areas and intensive agriculture, on the other hand, are considered hostile landscape units as they cause landscape degradation and fragmentation, which are the main anthropogenic pressures to biodiversity.

For the mapping of favourable and hostile landscape units (Fig. 3), we used the Copernicus Land Local Component "Urban Atlas" 2012, enhanced by a wetlands layer produced in 2017 using EO and field observations. As favourable units, we considered water bodies, inland and coastal wetlands, lagoons, forests, grasslands, farmland areas

with low intensive agriculture, like pastures and complex and mixed cultivation patterns and green urban areas and sports and leisure facilities, which, although classified as Urban, have low (<10%) degree of imperviousness. In addition, we identified the “High Nature Value Farmland Areas” (HNV), adopting the methodology of Paracchini et al. (2008) (i.e. N2K Special Areas for Birds were used as IBA datasets were not available and datasets from IPA inventories and Prime Butterfly Areas were also not available). As hostile units, we considered transport networks, continuous and discontinuous urban fabric, isolated structures, industrial commercial public, military and private units, ports and airports, extraction and construction sites and intensive agriculture.

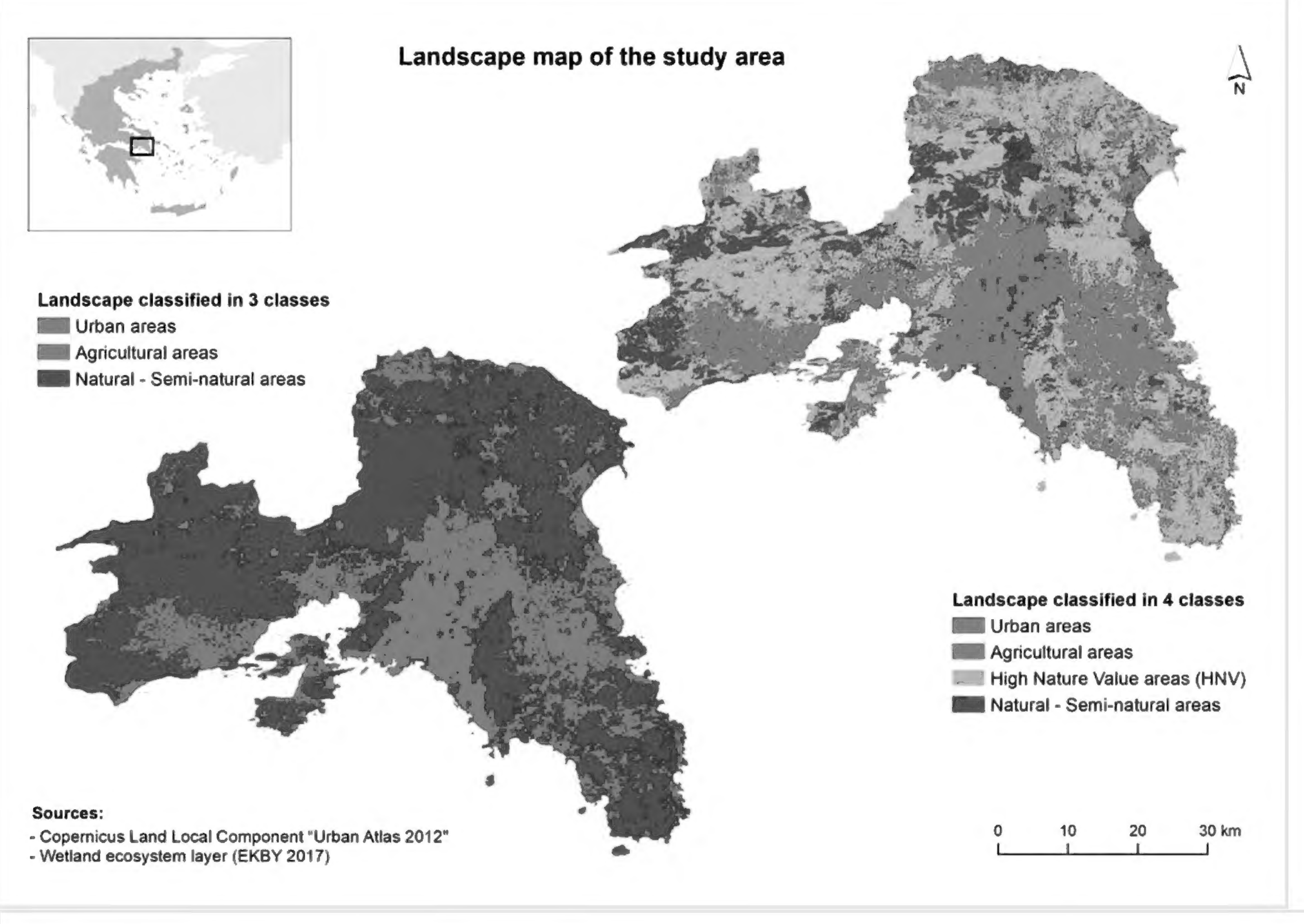

Figure 3.

Core map of the study area, classified in 3 classes (left) and in 4 classes (right) that also shows the High Nature Value areas.

Composite indicator for mapping and assessment of ecosystem condition

To assess the ecosystem condition, a Biodiversity State Indicator (BS) and an Anthropogenic Impact Indicator (AI) were combined, using a subjective equal weighting (EW) method, by assuming that both factors equally influence the condition. This composite Ecosystem Condition Indicator was calculated according to the following equation:

*Ecosystem Condition = 0.5 * Anthropogenic Impact + 0.5 * Biodiversity State*

It combines different sub-indicators that are based on an analysis of data underpinning: a) environmental quality expressed via the degradation of natural ecosystems due to

intensive agriculture and urbanisation, b) pressures from population density and c) biodiversity state, based on attributes monitored under the EU Nature Directives (Table 1). The weighting and normalisation of the ecosystem condition indicators, as well as of their sub-indicators, was decided by expert judgement after several iterations to obtain meaningful results. The suitability of weight and threshold values applies for the specific study area.

Table 1.

The composite Ecosystem Condition Indicator.

Ecosystem Condition Indicator (Natural Potential)	*Pressures and environmental quality composite indicator* **Anthropogenic Impact**	Landscape degradation (*environmental quality*)	SUB - INDICATORS
		Population density (*pressure*)	
	Ecosystem attributes (biological quality composite indicator) **Biodiversity state**	Habitats Condition	
		Species Condition	
		Population trends of breeding birds	
		Habitat Richness	
		Species Richness	
		Habitat Distribution pattern	
		Species Distribution pattern	
		Amount of common bird species	

Anthropogenic Impact Indicator

For the current study, the impact of anthropogenic pressures was assessed as a composition of the landscape degradation and the pressures from population density (Table 2), using a subjective weighting method since the “true” weights of each factor remain unknown. A higher weight was assigned to the landscape degradation, as it reflects the impact caused by several anthropogenic drivers of change. The following equation was used:

Table 2.

Sub-indicators used for the composite Anthropogenic Impact Indicator.

Anthropogenic Impact sub-indicators	**Data sources**	**Temporal extent**	**Values examined**	**Complexity**	**Calculation approach**

Landscape degradation	• Copernicus Land Local Component Urban Atlas • Wetlands layer	• 2012 • 2017	Nature dominance. Landscape degradation	Medium	Spatially examined, based on a pattern analysis of the landscape map and further reclassification to examine the landscape degradation based on the degree of nature dominance. Scores are applied from 1 to 6 to indicate 'very high degradation' to 'none'.
Population density	• Census (Hellenic Statistical Authority) • Greek municipalities spatial units • Copernicus Land Local Component Urban Atlas	• 2011 • 2010 • 2012	Population density (people per sq. km area of municipality), Built-up urban areas.	Simple	Spatially examined based on population density, downscaled to the built-up urban areas. Scores are applied from 1 to 6 to indicate 'very dense' to 'very sparse' population.

*Anthropogenic Impact = 0.6 * Landscape degradation + 0.4 * Population density*

For the landscape degradation, a pattern analysis was firstly performed to the core landscape map using the Landscape Mosaic tool of GuidosToolbox (v. 2.6) software (Vogt and Riitters 2017). In particular, a tri-polar classification model was applied at pixel level, using the relative proportions of three classes (natural, agriculture and developed) in a moving window of 35x35px surrounding each pixel. Using the critical values of 10%, 60%, and 100% along each axis, the tri-polar map resulted to 19 mosaic classes, indicating the human influences. These classes were condensed into six (6) classes to highlight landscape mosaics within natural background and to identify human–natural interface zones (Riitters et al. 2010) and scores from 1 (very high) to 6 (none) were applied to reflect the intensity of landscape degradation (Fig. 4).

By integrating population density in the Anthropogenic Impact indicator, we intended to reflect the potential pressures on ecosystems, given that population growth is considered as a key driver associated with increasing food and energy demands, as well as with evolving consumption patterns, the loss of global biodiversity, the degradation of natural ecosystems and water pollution (EEA 2015a).

For mapping population density, the most recent census of the Hellenic Statistical Authority for 2011 was used. Then, built-up areas were extracted from the landscape map and were used for downscaling population data and excluding areas of unpopulated land (Fig. 5). It should be noted that the density data classification may influence the appearance and final ranking of the population density map. The classification applied is non-linear, so lower

density classes represent tens of people per square km (very sparse population), while top classes represent tens of thousands of people per square km (very dense population).

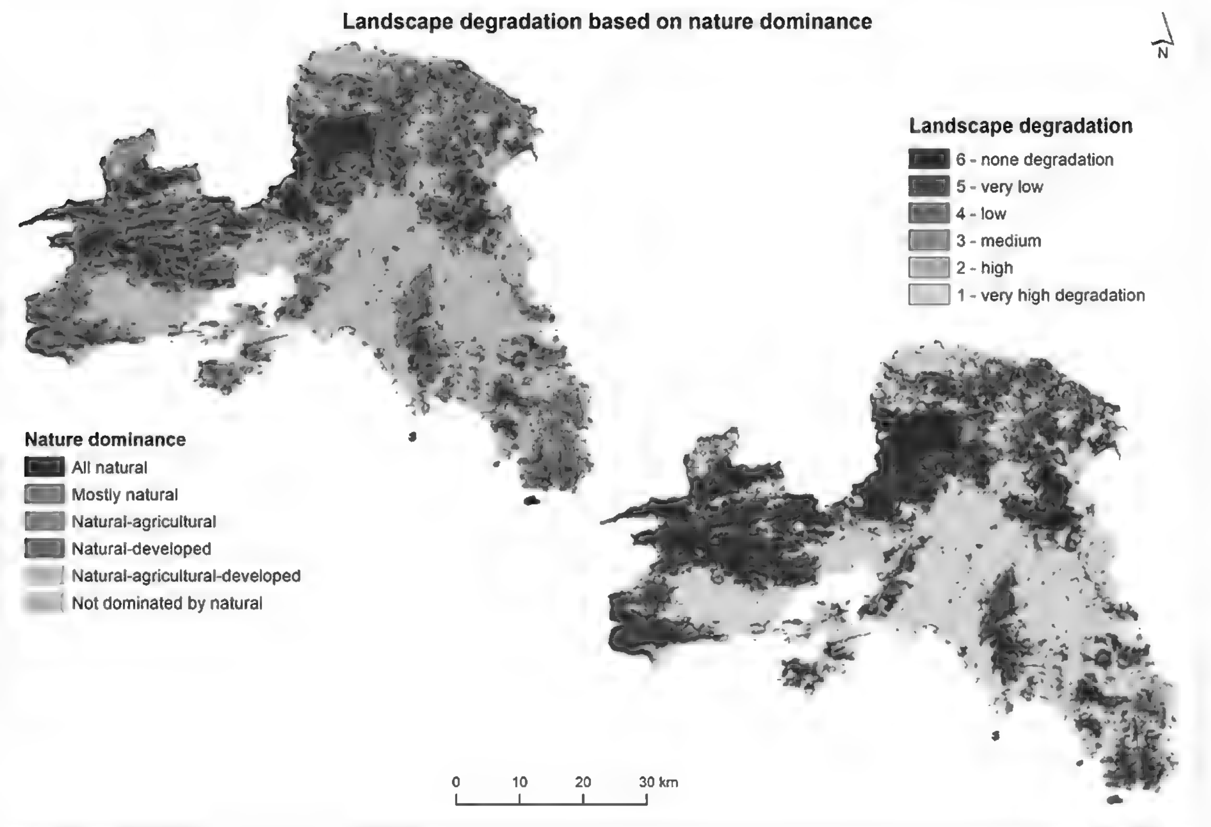

Figure 4.

Map of Landscape degradation based on nature dominance.

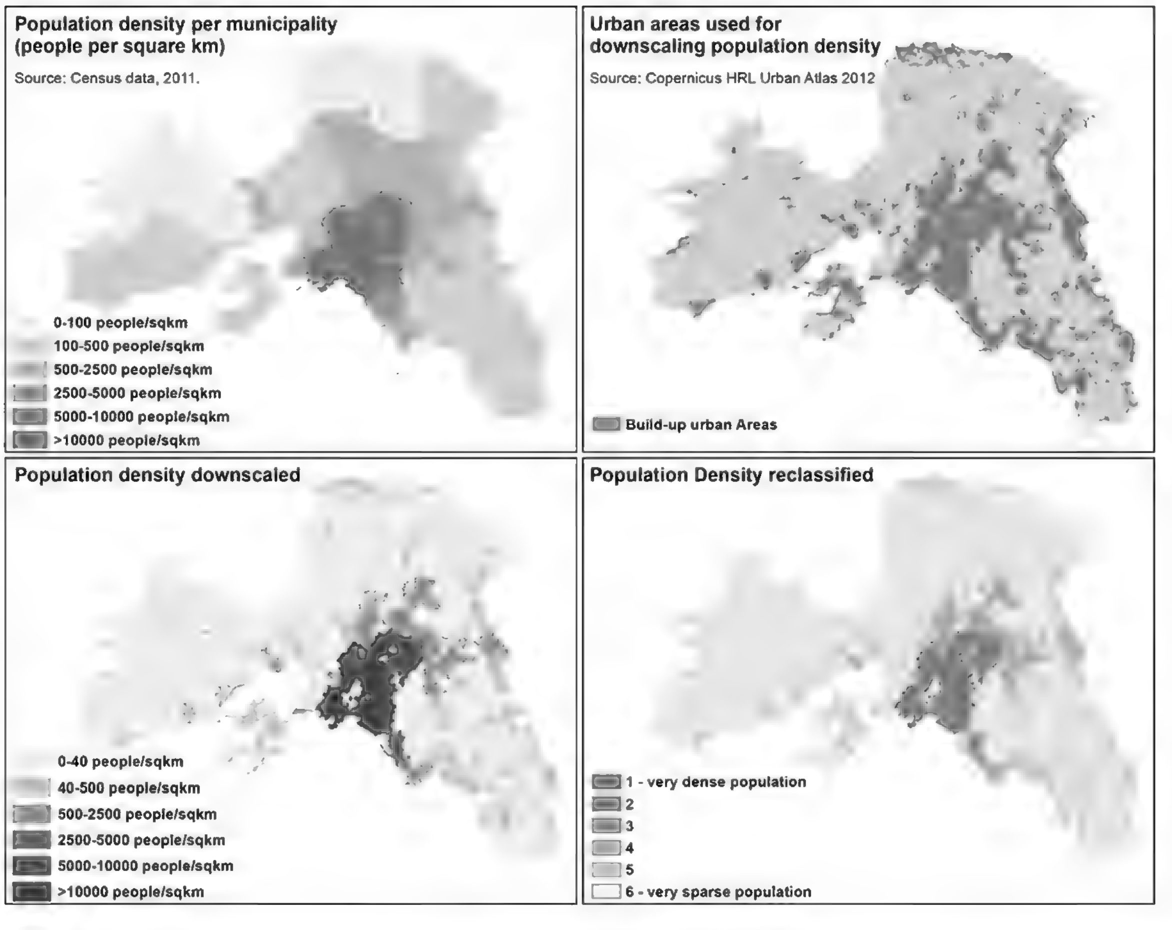

Figure 5.

Map of Population density.

Fig. 6 spatially presents the Anthropogenic Impact Indicator in a scale from 0 to 5, indicating landscape units with very high to very low impact.

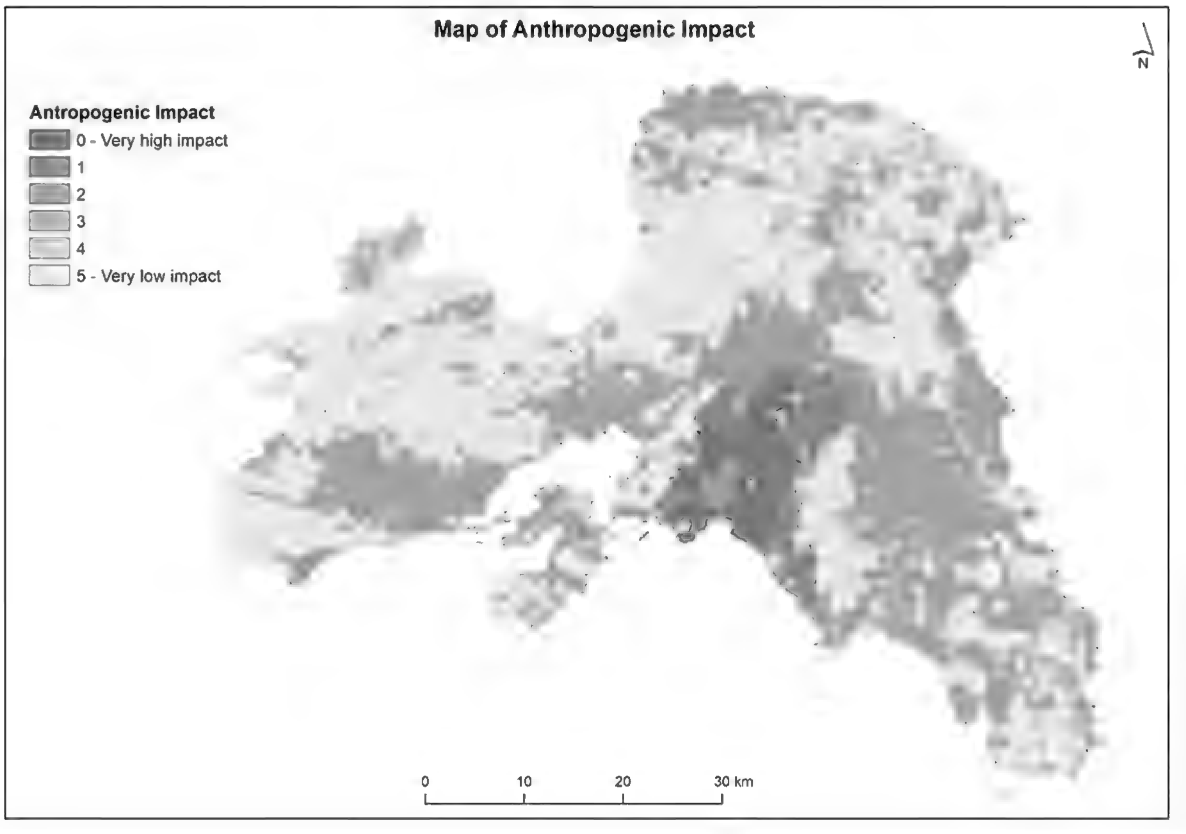

Figure 6.

Map showing Anthropogenic Impact.

Biodiversity State Indicator

EU Nature Directives provide key inputs that can be used as indicators for assessing ecosystem condition and trends (Parrish et al. 2003; Salomidi et al. 2012). In the current study, the Biodiversity State indicator has been designed, based on biodiversity attributes monitored under the EU Nature Directives (Art. 17, Art. 12, N2K SDFs, PanEuropean Common Bird Monitoring Scheme-PECBMS).

The Biodiversity State indicator constitutes a concrete element of the ecosystem condition assessment. It incorporates eight (8) sub-indicators (Table 3): Habitat condition, Species condition (flora and fauna), Population trends of breeding birds, Habitat richness, Species richness, Habitat distribution pattern, Species distribution pattern and Richness of Common birds. For their assessment, methodological and technical aspects (data availability, temporal extent, values examined, complexity, calculation approach) have been investigated (Table 3).

Each sub-indicator is calculated separately at cell level and its values are scanned and ranked as bad/low (1), moderate (2) and good/high (3), based on value thresholds assigned by experts.

Table 3.

Sub-indicators used for the composite Biodiversity State Indicator, based on biodiversity attributes monitored under the EU Nature Directives.

Biodiversity State sub-indicators	Data sources	Temporal extent	Values examined	Complexity*	Calculation approach
Habitat condition (Canterbury et al. 2000)	• Art. 17 • N2K SDFs	2007-2014	Habitat conservation status and conservation degree	Complex	Spatially examined, based on habitats distribution (10x10 km cells). Cells are ranked based on combination of habitat conservation status and conservation degree (if in a N2K site, at least 20% of cell's area). Weighted Average is applied to calculate the final cell score, by summing all habitats present at the cell. Weights are assigned to habitats, based on their distribution at national level, for a given biogeographical region. Final scores are reclassified to "bad", "moderate" and "good".
Species condition *(flora, fauna)* (Nagendra et al. 2013)	• Art. 17 • N2K SDFs	2007-2014	Species conservation status and conservation degree	Complex	Spatially examined, based on species distribution (10x10 km cells). Calculation is similar to the Habitat condition. Final scores reclassified to "bad", "moderate" and "good".
Population trends of breeding birds (Carignan and Villard 2002)	• Art.12 • N2K SDFs	2008-2014	Population trend	Complex	Spatially examined, based on the breeding birds distribution (10x10 km cells). Calculation is similar to the Habitat condition. Final scores are reclassified to "low", "moderate" and "high".
Habitat richness (Tews et al. 2003)	• Art.17	2007-2014	Count of different habitat types	Simple	Spatially examined based on habitats distribution (10x10 km cells), calculated as the count of habitat types that are present in a cell, compared to the sum of the habitat types in the study area. Classified as "low", "moderate" and "high".
Species richness (Pollock et al. 1998)	• Art.17 • Art.12	2007-2014	Count of different fauna and flora species and of breeding birds	Simple	Spatially examined based on species (flora, fauna) distribution (10x10 km cells), calculated as the count of species that are present in a cell, compared to the sum of species in the study area. Classified as "low", "moderate" and "high".

Habitat distribution pattern (Riitters et al. 1997)	• Art.17	2007-2014	Landscape patterns of distribution-abundance of habitat types	Medium difficulty	Occurrences of each habitat in the study area. Spatially examined, based on habitat distribution (10x10 km cells) and calculated at cell level according to the habitat type with least occurrences in the study area. Classified as “low”, “moderate” and “high”.
Species distribution pattern (Landres et al. 1999)	• Art.17 • Art.12	2007-2014	Landscape patterns of distribution-abundance of species	Medium difficulty	Occurrences of each species in the study area. Spatially examined, based on species (flora, fauna and birds) distribution (10x10 km cells). Calculated similarly to the habitat distribution pattern indicator. Classified as “low”, “moderate” and “high”.
Richness of Common birds (Levrel et al. 2010)	• Art.12 • PECBMS	2008-2014	Count of common species	Simple	Spatially examined, based on the common birds’ distribution (10x10 km cells). It is calculated as the count of common bird species that are present in a cell, compared to the sum of common birds in the study area. Classified as “low”, “moderate” and “high”.

** Complexity refers to the level of calculation difficulty, according to the requirements of GIS and database skills and scientific knowledge, for the harmonisation, synthesis and interpretation of different EU biodiversity datasets (geospatial and tabular).*

In particular, for two of the most complex sub-indicators, which are the “Habitat condition” and “Species condition”, we used data on the assessment of conservation status reported under Art. 17 for the monitoring period 2007-2012 (which in Greece, was extended to 2014). These data refer to the overall assessment of habitat types/species conservation status at the biogeographical region within a Member State. Their accompanying geospatial data map the distribution of habitat types/species at cell level, using the EEA Reference Grid of 10 km. To assess the condition at the study area, the values of conservation status of habitat types/species (U2: Bad, U1: Inadequate, FV: Favourable/ Adequate, XX: Unknown) were downscaled at the cell level. For the evaluation of cells that are inside Natura 2000 sites, these data were also combined with the degree of conservation (A for excellent, B for good and C for average or reduced) of the natural habitat type concerned or of the habitat which is important for the species concerned, as this is reported in the N2K SDFs. The calculation approach of these sub-indicators, requires a first spatial examination of the occurrence and diversity of habitats/species at the cell, based on the geospatial data on habitats/species distribution. An initial scoring of the cells per each habitat type/species is then applied with a rule-based decision method (Table 4). Scores are from 0 to 6, indicating worst to best condition.

Table 4.

Rule-based decision for the initial cell scoring of condition for each habitat type/species.

SCORE	INITIAL SCORING DECISION
0	cells where no habitats/species occur
1	cells where conservation status is unknown data (XX) and are not in N2K site
	cells where conservation status is unknown data (XX) and conservation degree is C
	cells that have U2 conservation status and C conservation degree
	cells that have U1 conservation status and C conservation degree
	cells that have U2 conservation status and are not in N2K site
2	cells that have FV conservation status and C conservation degree
	cells that have U1 conservation status and are not in N2K site
3	cells that have U1 conservation status and B conservation degree
	cells that have U2 conservation status and B conservation degree
4	cells that have FV conservation status and are not in N2K site
	cells that have FV conservation status and B conservation degree
	cells that have U2 conservation status and A conservation degree
5	cells that have U1 conservation status and A conservation degree
6	cells that have FV conservation status and A conservation degree

Exceptions:

If a habitat/species conservation status is U2 or U1 and a N2K site covers <10% area of the cell, we consider that the “bad” conservation status dominates any value of its degree of conservation and ranks 1 and 2 are assigned accordingly, as is in the case of cells that are not in a N2K site.

For the synthesis of the Habitat/Species Condition at the cell, weights are assigned to each habitat/species, based on the percentage of the habitat/species distribution at the cell, compared to its total distribution (total number of cells where the habitat/species occurs) at national level. The final composite score of the cell is calculated based on the following formula:

$$\mathbf{S = \Sigma w_i x_i / \Sigma w_i}$$

S: is the Habitat/Species Condition composite score of the cell
x_i: initial scores of each habitat/species
w_i: weights assigned to each habitat/species that occurs at the cell
$\Sigma w_i x_i$: sum of weighted habitats/species scores
Σw_i: sum of weights

The calculation of the “Population trends of breeding birds” sub-indicator, follows a similar approach, by using data on the assessment of population trends of breeding birds that are reported under Art. 12 for the monitoring period 2008-2012 (which in Greece, was extended to 2014), combined with their spatial distribution at 10x10 km cells.

Geospatial data on habitat types/species distribution reported under Art.17, is also used for evaluating the habitat and species richness and the habitat and species distribution patterns sub-indicators. Habitat and species richness are calculated at each 10x10 km cell, and are expressed by the count of all habitats/species that occur at the cell, divided to the total count of all habitats/species that occur at the study area. Scores are assigned based on the values range at the study area (habitat richness varies from 3%-53% and species richness from 8%-44%). Scoring from 1 to 3 was assigned as follows: 1 (low) = <10%, 2 (moderate) = 10-40%, 3 (high) = >40%.

The calculation of the habitat and species distribution patterns sub-indicators is based on the sum of occurrences (distribution cells) of each habitat/species in the study area. Given that the study area is covered by 54 cells (of 10x10 km), all cells are scored by assigning lower values to those that have habitats/species with high distribution at the study area and higher to those with limited distribution. Scores from 0 to 3 were assigned based on the following rules:

- 0: cells where no habitats occur.
- 1 (low): cells that have at least one habitat with >30 occurrences in the study area and none with <30 occurrences.
- 2 (moderate): cells that have at least one habitat with 10-30 occurrences in the study area and none with <10 occurrences.
- 3 (high): cells that have at least one habitat with <10 occurrences in the study area.

For the “Richness of common birds” sub-indicator, we identified common birds that occur in Greece from the PECBMS database and evaluated their richness, based on their spatial distribution, as this was reported under Art.12. Values range at the study area vary from 28-84%. Scoring from 1 to 3 was given using the following threshold values: 1 (low) = <30%, 2 (moderate) = 30-60%, 3 (high) = >60%.

For the overall synthesis of the above 8 sub-indicators, a GIS-based Multi-Criteria Decision Analysis (MCDA) was applied, by using a decision rule procedure for combining the sub-indicator scores, in order to arrive at a particular evaluation at cell level (Fig. 7). Cells were ranked in a scale from 0 to 5, indicating landscape units with: No biodiversity or unknown/ no data (0), Bad (1), Inadequate (2), Average (3), Adequate (4) and Excellent Biodiversity State (5). Finally, Biodiversity State values were downscaled to the favourable landscape units following the majority rule (Fig. 8). Hostile units (urban areas and intensive agriculture) were assigned with the value 0 (No biodiversity).

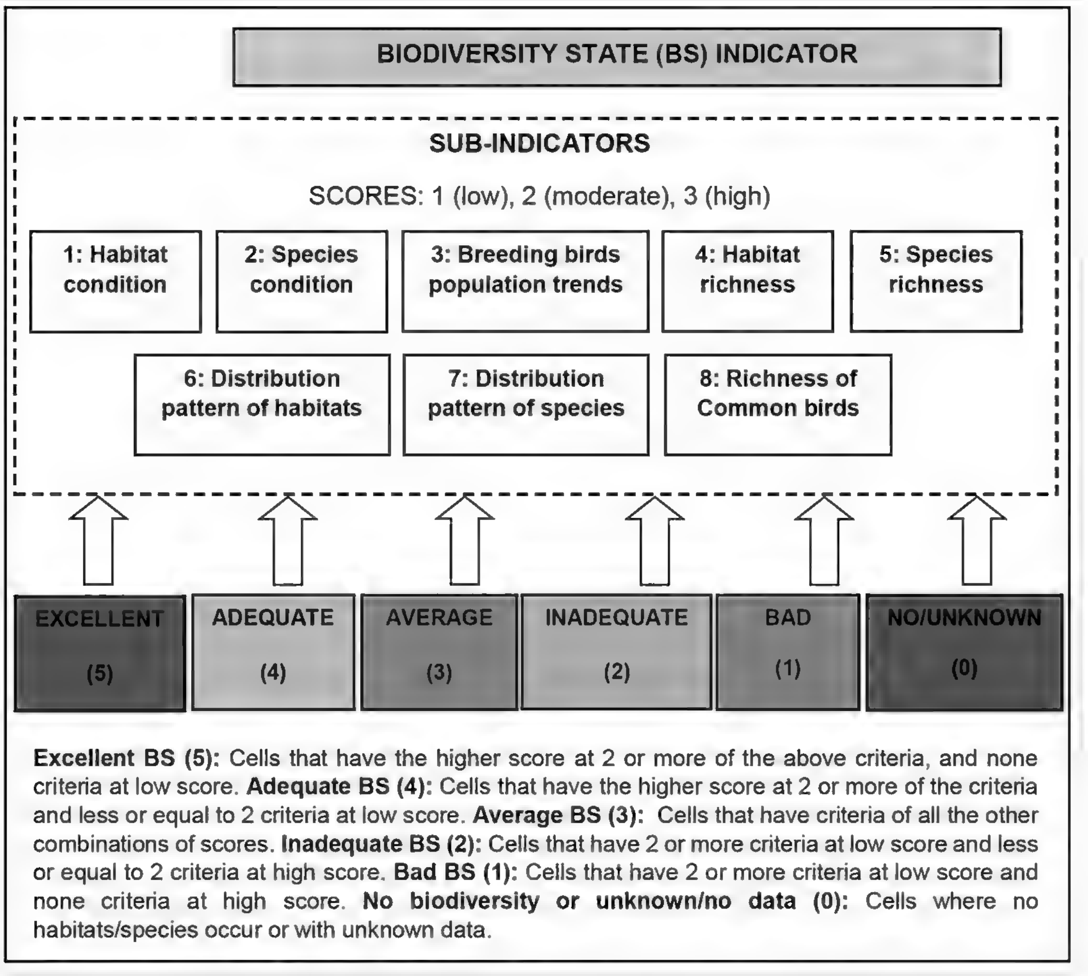

Figure 7.

Diagram of the Biodiversity State Indicator, based on biodiversity attributes monitored under the EU Nature Directives.

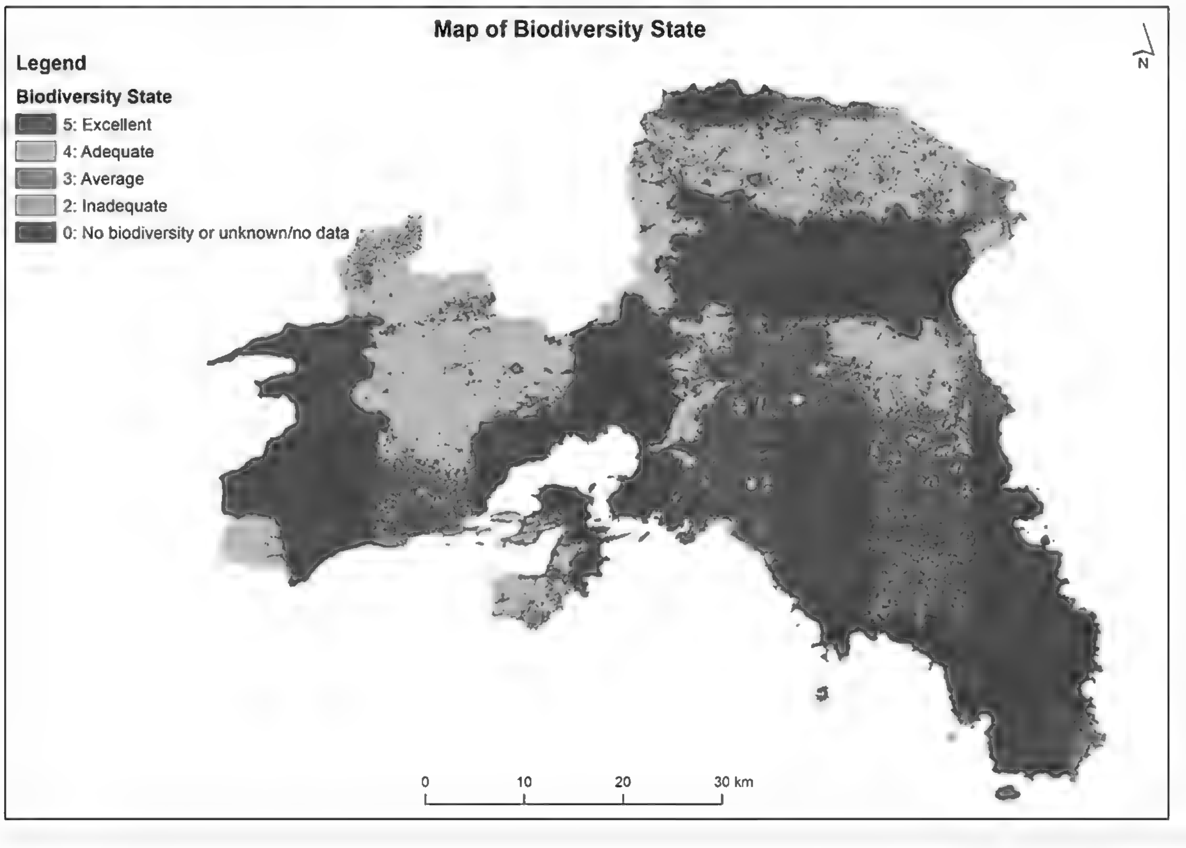

Figure 8.

Map of Biodiversity State, downscaled to the favourable landscape units.

Integration of the EU Biodiversity Strategy demands into mapping and assessment of the habitat maintenance ES

According to our conceptual framework, the habitat maintenance ES Supply assessment is based on the natural potential values and uses, as additional input, the protection level that is applied at nationally designated areas, as an instrument of the EU Biodiversity Strategy to 2020. Table 5 presents the matrix that is proposed for the quantification and mapping of the habitat maintenance supply. It integrates the protection level as a response to the decline in Biodiversity State and consequently to the decline of the natural potential overall, based on the hypothesis that, if a landscape unit: (i) has weak (not related to nature conservation) or no protection status, then the natural potential may be reduced; (ii) has medium protection status (IUCN management categories: III, IV, V, VI), then the natural potential equals to the supply; (iii) has strict protection status (IUCN management categories: Ia, Ib, II), then the natural potential can be increased.

Table 5.

Proposed matrix for the qualitative ES Supply assessment approach, based on the relationship between the natural potential and the protection level (as additional input).

ES Supply Matrix						
Protection level	**Natural Potential**					
	0 **No potential**	**1** **Very low**	**2** **Low**	**3** **Medium**	**4** **High**	**5** **Very high**
High	0	2	3	4	5	5
Medium	0	1	2	3	4	5
Weak/No	0	1	1	2	3	4

For SPUs, we considered the landscape units with medium (3), high (4) and very high (5) ES supply. Units of very high natural potential and of high protection level were spatially identified as ES hotspots of biodiversity conservation and key-elements of the landscape. If a landscape unit has no potential to provide ES, the protection level does not influence the supply at all.

For SBAs, we considered the N2K sites, given that a specific demand for the habitat maintenance supply is localised in the N2K network, which support the conservation of habitats and species of Community interest, listed under both the Birds Directive and the Habitats Directive, the cornerstones of the EU's biodiversity policy. For SCUs, we considered those wetland ecosystems that can connect non-adjacent SPUs and SBAs and influence the habitat maintenance supply. This derives from EU Habitat and Birds Directives (Article 10 and 4, respectively) which underscore wetlands importance as stepping stones or corridors and urge for their conservation as key landscape features that can improve the coherence, connectivity and resilience of the broader protected area network. It also derives from the EU Green Infrastructure Strategy which encompasses ecological networks but goes further with the inclusion of elements even in urban environments.

To address the challenges set by the EU Biodiversity Strategy to 2020 to implement effective management and restoration of areas of high biodiversity value both within and outside the N2K network (Targets 1 and 2 of the EU Biodiversity Strategy), we assessed the spatial relationships amongst the SPUs, the N2K sites (as SBAs) and wetlands (as SCUs). For this scope, we performed a structural connectivity analysis. Additionally, a distance-based wetland connectivity analysis was performed to complement the results.

The structural connectivity analysis was performed with the Morphological Spatial Pattern Analysis (MSPA) of the GuidosToolbox software package (v. 2.6), by using as core unit (foreground) the SPUs and SBAs. The MSPA-analysis was converted into a Network using the Guidos NW Components image analysis. For the distance-based wetland connectivity analysis, we calculated the wetland connectivity indicator (< 10 km from other wetland / > 10 km from other wetland), as this is proposed by the 5th MAES report (Maes et al. 2018). The 10 km distance corresponds to the median dispersal distance that covers the majority of terrestrial species dispersal demands (Saura et al. 2017).

Results & Discussion

Ecosystem condition and links with the habitat maintenance ES supply

The mapping and assessment of ecosystem condition (Fig. 9) revealed that the study area has a promising natural potential to supply the habitat maintenance ES (45% of the landscape extent with medium, high and very high values). According to Fiedler et al. (2008), as well as Ntshane and Gambiza (2016), environmental management, focused on the habitat condition, could improve ES.

An interesting finding is that significant extents of areas of very high natural potential (Fig. 9), fall outside N2K sites (66%) and nationally protected areas (56%). This is related with their excellent biodiversity state and specifically with rich biodiversity in bird and common bird species. They are located in High Nature Value (HNV) landscape units of herbaceous vegetation (natural grassland, moors etc.). At the same time, the natural potential values vary inside a protected area, even in cases where strict protection applies.

Overall, Fig. 9 provides spatially explicit information to initiate several policy discussions. It can be integrated into future regional action plans for:

- preserving the very high natural potential areas which are located outside the N2K network or national protected areas (strict or moderate protection);
- restoring the patches of low natural potential, which are located inside N2K sites or protected areas;
- documenting the need to improve the protection status of some N2K sites (i.e. site GR3000014) which are found to have very high natural potential;
- prioritising conservation planning, according to the assessment of ecosystem condition as very high, high, medium.

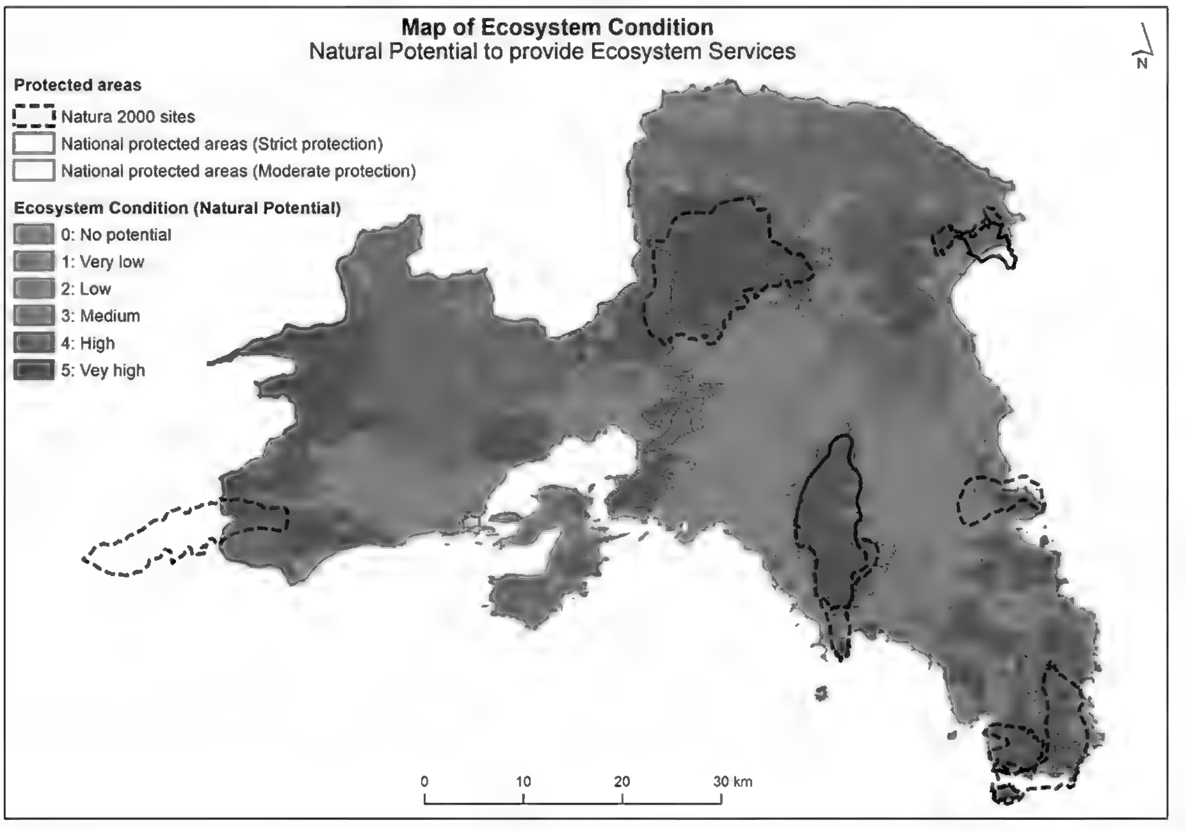

Figure 9.

Map of Ecosystem Condition – Natural Potential to provide Ecosystem Services.

By combining the Ecosystem Condition Indicator map with the protection status, we mapped and assessed the habitat maintenance ES supply (Fig. 10).

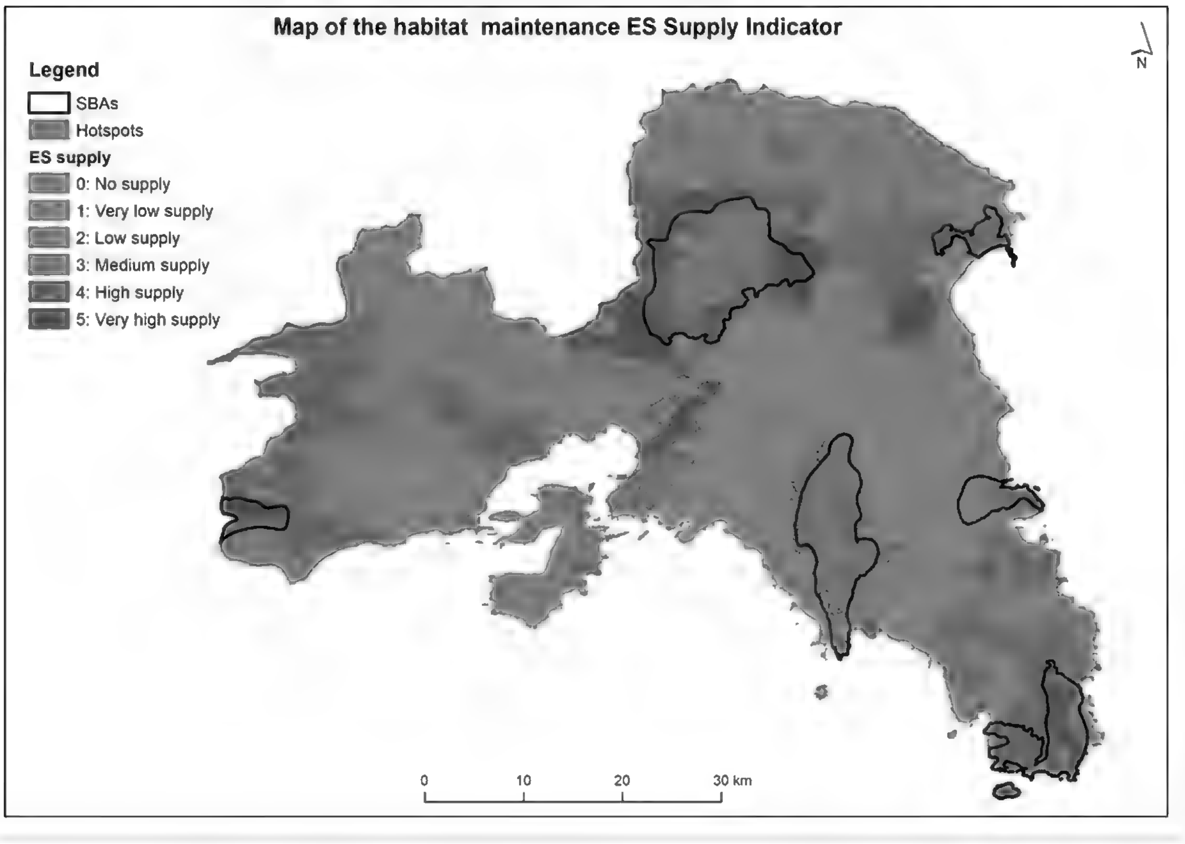

Figure 10.

Map of the habitat maintenance ES supply (Hotspots are areas of very high natural potential and high protection).

Results demonstrate that not all of the surface area of the landscape units with high and very high natural potentials, maintain their capacity to deliver the habitat maintenance ES. A significant part (23% of their total surface area), is not ending up to high and very high ES supply, as a consequence of weak (or lack of) protection. In particular, SPUs and hotspots of biodiversity conservation were spatially identified. SPUs cover 54.2% of the study area (24.82% of medium supply, 17.73% of high supply, 11.65% of very high supply). Hotspots cover 5.8% of the study area and almost half (42.6%) of the extent of the SBAs. Still, 11% of the SBAs' (N2K sites) extent fall out of SPUs. It is also observed, that 42% of the High Nature Value areas have very high and high natural potential to provide ES. As already described above, such results provide useful spatially explicit information that can help prioritisation in conservation planning. The mapping of the habitat maintenance ES supply (Fig. 10) represents the final synthesis of data and provides great potentials for further research on the spatial characteristics that protected areas should engage, such as, for example, the surface area of protected areas (Green and Paine 1997; Groves et al. 2002; Leroux and Kerr 2012; Mikkonen and Moilanen 2013).

Spatial relationships amongst the service providing units, the Natura 2000 sites (benefit areas) and wetland ecosystems

The structural connectivity analysis, along with the distance-based wetland connectivity showed different spatial relationship patterns amongst the SPUs, the N2K sites (as SBAs) and wetlands (as SCUs).

The structural connectivity analysis (MSPA) resulted in a network of 111 simple subnets (physically isolated nodes) and 316 complex subnets (structurally connected areas that consist of nodes which are physically connected with links).The Guidos NW Components image analysis showed an overall degree of connectivity (relative Equivalent Connected Area metric - ECA_rel) that equals to 58%. This metric summarises the percentage of reachable area in the network compared to the total study area (Saura et al. 2011).

Fig. 11 shows the NW components, the SBAs and the wetland ecosystems. Five of the NW components (the largest connected areas and with the highest number of links), include in their extent the SBAs (9 N2K sites) and 16 out of the 42 wetland sites and cover a significant part (44%) of the study area (see Fig. 11 and Table 6).

Table 6.

Statistics of the 5 structurally connected areas which include the 9 N2K sites (SBAs) along with the wetland sites which are found in each of them (16 out of 42 sites) Wetland ID corresponds to the IDs of the 42 wetland sites IDs (Suppl. material 1).

Connected area (NW component)	Links	Area (ha)	SBAs(N2K sites)	Wetland ID	Wetland name
1	440049	13703.72	GR3000014 GR3000005	3	Keratea Estuary
				18	Alykes Anavissou Coastal marsh

				22	Epixomatoseis Lavriou Coastal marsh
				23	Legrena Coastal marsh
				24	Limanaki Thorikou Coastal marsh
				32	Pefkou Lagonisiou Coastal marsh
				16	Agios Nikolaos Coastal marsh
2	62126	10404.34	GR3000015 GR3000006	13	Vouliagmeni Lake
				25	Loumparda Coastal marsh
3	1920293	78435.88	GR3000001 GR2530005	34	Psatha Vilion Coastal marsh
				37	Mpeletsiou Manmade lakes
4	39954	2690.60	GR3000004	20	Vravrona Coastal marsh
				36	Piges Erasinou Inland marsh
5	955196	29184.25	GR3000016 GR3000003	35	Shinias Marathona Coastal marsh
				40	Marathonas Reservoir
				30	Brexiza Coastal marsh

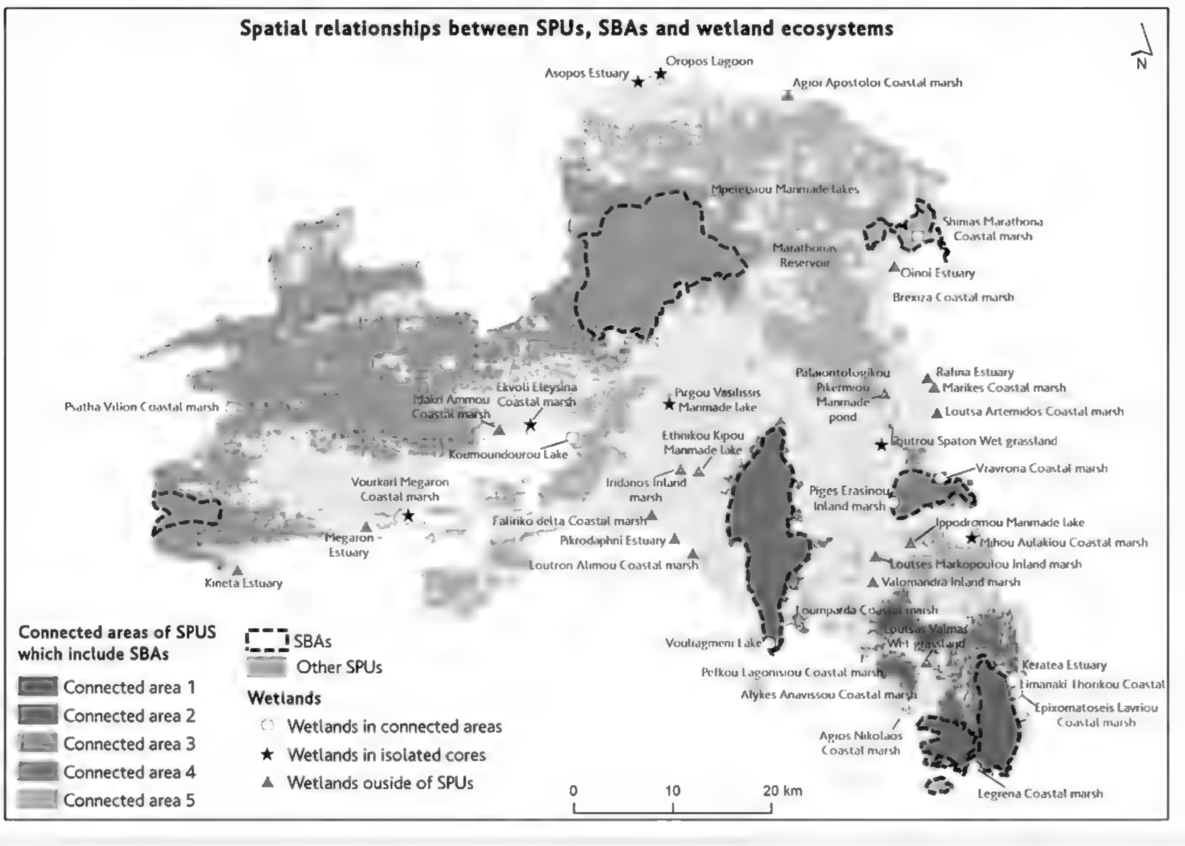

Figure 11.

Map depicting the structurally connected areas of SPUs (NW components) and their spatial relationships with SBAs and wetland ecosystems.

The distance-based wetland connectivity indicator revealed interesting results for the wetland network, as key features of the studied landscape. Indicator values below one (<

1) mean that more wetlands are far (> 10 km) than close (< 10 km) from the examined one, indicating low connectivity. In the study area, the values ranged from 0 to 0.20, which is considerably lower than 1, demonstrating that Attica wetlands are far (> 10 km) from each other. However, as it was noted from 1995 (Communication from the Commission to the Council and the European Parliament/ COM 1995), wetlands should be conserved as forming a global interconnecting network, often between distant areas. In addition, GI elements are not necessarily physically connected to each other.

Results show (Fig. 11, Table 6) that N2K sites are not structurally connected to each other, apart from those which overlap (SACs and SPAs) and from the two sites which are located in connected area 3. This finding is in line with Estreguil et al. (2014) who found that the entire N2K network of Greece is the least connected amongst the EU countries, since the original goal of its establishment did not integrate the connectivity aspect.

Considering the vital investigation of the connectivity of N2K sites with a view to enhancing the ecological coherence of the network (Verschuuren 2013), four dominant spatial relationship patterns are identified in order to contribute to shaping management and conservation actions, especially outside their boundaries:

(i) **N2K sites are surrounded by connected SPUs of extended width.** This pattern applies in structurally connected areas 3 (78435.88 ha) and 5 (29184.25 ha), which cover the largest part of the study area (36%) and create a continuous connected zone from the west to the eastern north part. An interesting finding is that an area of 47916 ha (61% of connected area 3) and an area of 24421.97 ha (83.66% of connected area 5) with high value for biodiversity (medium, high and very high supply) are located out of the N2K sites and in unprotected land (weak or no protection). The results document that connectivity of the respective N2K sites is fulfilled at regional level and indicate the spatial extent of unprotected areas which should be conserved and integrated in the management plans of N2K sites. For wetlands, another important finding is that Psatha Vilion Coastal marsh (ID: 34) demonstrates no wetland connectivity with the other Attica wetlands, implying its significance as a unique habitat for aquatic life.

(ii) **N2K sites are surrounded by connected SPUs of limited width.** This pattern is identified in the two neighbouring coastal N2K sites which are located in connected area 1 (13703.72 ha). In this case, an area of 7500.60 ha with high value for biodiversity (medium, high and very high supply) is located out of the N2K sites in unprotected land (weak or no protection). This area includes 7 coastal wetland sites (Table 6) which contribute to the habitat maintenance supply, especially for the benefit of aquatic life. The results document the connectivity of the 2 N2K sites with the surrounding natural areas and raise policy discussions as above.

(iii) **N2K sites almost coincide with connected SPUs.** This pattern applies in structurally connected areas 2 (10404.34 ha) and 4 (2690.60 ha). The surrounding landscape of the respective N2K sites provides no “habitat maintenance” ES supply. This result documents that species “survival” is restricted inside the sites’ boundaries and raise policy discussions

for specific management measures (i.e. the need for environmental friendly activities outside their boundaries)

(iv) **Stepping stone pattern of wetlands.** Twenty six (out of a total of 42) wetlands are not structurally connected with the N2K sites. Seven wetlands are located in isolated SPUs (Fig. 11, those with black asterisk) and the rest 18 wetlands are located outside of SPUs (Fig. 11, those with red triangle), in hostile areas. Only one wetland (ID: 14 "Koumoundourou Lake") is located in a connected area of SPUs. The results document that more than half of Attica wetlands act as Service Connecting Units being, in most cases, the only natural sources in the surrounding landscape and indicate the need for their protection. Combined with the results of the distance-based wetland connectivity, they can assist in conservation planning. For example, three wetlands (ID: 8 "Valomandra Inland marsh", ID: 9 "Loutrou Spaton Wet grassland" and ID: 10 "Loutsa Valma Wet grassland"), which are found in isolated cores or in hostile areas, appear with the higher possible connection, compared to the others. This finding documents the need to conserve these wetlands as a complex of sites. Similarly, other studies found that habitat connectivity assists in biodiversity conservation, especially in the case of human-induced ecosystems (Fischer and Young 2007; Brudvig et al. 2009). Additionally, as highlighted by Groot et al. (2012), ecosystem services from a specific wetland will be of higher value if there are fewer other wetlands in the vicinity. On the other hand, two wetlands (ID: 4 "Kineta Estuary" and ID: 17 "Agioi Apostoloi Coastal marsh") which are found in totally hostile landscape areas of no or low ES supply, demonstrate no connectivity. Needless to say, these wetlands should constitute priority sites as biodiversity "islands". The above outcomes identify the significant role of wetlands as alternative landscape features to be conserved (Merken et al. 2015).

Methodological challenges

The presented methodological approach takes a step forward, by designing a composite indicator for assessing ecosystem condition, in line with requirements set by the relevant MAES indicator framework (i.e. scientifically sound, supporting environmental legislation, policy relevant, include habitat and species conservation status, spatially explicit, sensitive to changes) (Maes et al. 2018). It is based on EO mapping products, which are coupled with EU biodiversity datasets on habitats and species and are post processed (i.e. spatial analysis and landscape models) and reclassified to indicate biological quality and anthropogenic impact. Their regular update (EO revisits and MS reporting) is a major asset of the proposed methodology in monitoring status and trends of ecosystem condition.

Although, EU Biodiversity attributes (reported under Art. 17 and Art. 12 of the Habitats and Birds Directives) are proposed as metrics to assess biological quality and ecosystems condition (Maes et al. 2018), according to our knowledge, their synthesis had not been addressed so far. In our study, we spatially examined these attributes at cell level (10x10 km) to calculate 8 sub-indicators. For their synthesis, specific rules were decided to come up with the overall assessment of the Biodiversity State of each cell. Additionally, to overcome the bottleneck of having data on the conservation status of habitats and species

and population trends of birds at national level, with spatial distributions at cell level, we assigned weights at each habitat/species/bird. These weights were based on their distribution at national level (for a given biogeographical region). Impacts on the normalisation of the final cell scores to the 1-3 scale (bad, moderate, good) of the sub-indicators and the suitability of weight and threshold values should be considered.

The next steps of our research are dedicated to the enhancement of the composite Ecosystem Condition Indicator with additional sub-indicators, based on data availability. A methodological challenge is to integrate the temporal variability that characterises ecosystems and their services and use additional EO mapping products, such as: Land Use - Land Cover changes, Land Surface Temperature, Soil moisture etc. The impact of natural drivers of change (i.e. exposure to drought, floods), along with other EU policy datasets relevant to anthropogenic pressures (i.e. Nitrates Directive 91/676/EEC) could also be integrated. However, although it is challenging to study the trends in the improvement or deterioration of the state of biodiversity, the EU national reporting process (to measure progress on the implementation of Nature Directives) does not allow true comparisons. Reported changes might not be genuine changes, but are associated with improved knowledge, the use of more accurate data or the use of different assessment methods.

With regards to the prioritisation of conservation and restoration decisions, the spatial analysis could be improved by incorporating the occurrence of EU priority species and of EU IUCN red lists of threatened habitats, species and ecosystems.

The transferability of these indicators at national or EU level could be further tested and improved to be used as a standard element in ES supply assessments. Such indicators could support the preparations for the Post-2020 Biodiversity Framework, as well as the 2030 Agenda for Sustainable Development, specifically by contributing to the achievement of SDG targets 6.6 and 15.9, to protect and restore water-related ecosystems and to integrate ecosystem and biodiversity values into national and local planning.

Conclusions

The proposed conceptual framework has been developed with a view to supporting and preserving biodiversity beyond protected networks and integrating wetlands protection into conservation planning. EO mapping products were coupled with EU biodiversity datasets, as a technical solution for the assessment and mapping of ecosystem condition and its potential to supply the “habitat maintenance” ES.

A key element in our study is the mapping and assessment of ecosystem condition, expressed as a function of Biodiversity State and Anthropogenic Impact indicators. The landscape units within the region of Attica with the most promising natural potential and the unprotected areas that possess the highest supply of the habitat maintenance ES, were mapped. An interesting finding is that, even if strict or moderate protection is applied to a designated area, the natural potential significantly varies inside it. Additionally, that a

significant part of the very high natural potential is located in unprotected land (outside N2K sites or nationally protected areas).

By using, as an additional input, the level of protection, as a human response to biodiversity decline and loss, the spatial extent of the habitat maintenance ES supply areas (SPUs) was quantified and mapped. Results demonstrated that not the full extent of areas of very high and high natural potentials maintain their capacity to supply the habitat maintenance, due to weak or lack of protection.

The role of Attica wetlands network has been underscored at landscape level. The results showed that wetlands are a source of the habitat maintenance ES supply, either by being part of connected SPUs or by representing stepping stones (isolated wetlands). The identified spatial relationship patterns amongst the SPUs, the N2K sites (as SBAs) and wetlands (as the SCUs), provide baseline information to prioritise conservation and restoration, in the context of the EU demands for no net loss and for a connected N2K network.

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Supplementary material

Suppl. material 1: List of wetlands of the study area doi

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Data type: docx
Brief description: List of wetlands of the study area.
Filename: Supplementary_1.docx - Download file (13.94 kb)